Proceedings of the 7th International Conference on HydroScience and Engineering

Philadelphia, USA September 10-13, 2006 (ICHE 2006)

ISBN: 0977447405

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MAXIMUM RAINFALL INTENSITY ANALYSIS USING L-MOMENTS IN SPAIN

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ABSTRACT

Flood predictions are frequently the basis for engineering works, structure designs, and land use planning, but quite often there are no gauged stations and consequently hydrometeorological models become an essential tool. These models require maximum rainfall intensity estimations -for different durations and return periods -an IDF law-. The IDF law presently used in Spain was developed in the seventies, and was based on an at-site analysis on the 21 available gauged stations at that time, using Gumbel distribution for adjustment.

The last paragraph is an invitation to the revision of methods and updating of data, as nowadays there are more gauged stations with sufficient records in the Spanish peninsular area. However, classical approach to the regionalization technique cannot be used due to scarce stations - there are 63 stations in 500.000 km^2- and great climate variability in short distances, from semi-arid in the southeast to Atlantic climate in the north. Thus, authors propose an "intra-station" regionalization, meaning, a regionalization in the same station.

In addition, they suggest new expressions, in order to extend results to the rest of the country. According to the practical character of this study, a GIS (Geographical Information System) application was developed , called –MAXIN- and it is available in the following web site:
http://www.forestales.upm.es/hidraulica/paginas/programas/programas.htm

1. INTRODUCTION

There are two reasons, for which a frequency study on annual maximum rainfall intensity requires a special analysis on the right hand tail of the distribution: Firstly, because it shows a very important asymmetry, and due to this, the model should reflect this characteristic. This implies, that when choosing a distribution, the shape parameter, related to asymmetry, needs to be carefully analysed; Moreover, coefficient of skewness is normally used. Secondly, estimations are also needed for high return periods. In consequence, they need to be especially stable in that part of the distribution and that requires an increase on sample size. As this is not possible, actual trends try to look for a robust method, that is, stable when there is insufficient data, and amongst others, a regional analysis is a robust method.

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Alternatively, the IDF (intensity-duration-frequency) relationship essentially used in Spain was developed in the seventies by the Environmental Office (Ministerio de Obras Públicas, Transporte y Medio Ambiente, 1978). It is based on an at-site analysis on the 21 available stations at the time. Gumbel distribution was used for adjustment, and in order to extend results to the rest of the country, a relation was established between intensity, for d-duration and T-return period, I (d,T), and the corresponding to 24-hours and the same return period. A potential function depending on a parameter was used and an Iso-line map was designed based on this parameter value in the 21 available stations.

According to this brief description of the actual situation in Spain, principal limitations to this law are based on insufficient data; not only scarce stations are used to define relationships, just 21, but record lengths are also limited, just up to the 60's. And according to methodology, Gumbel distribution, used for adjustment, shows a constant coefficient of skewness, 1,14, and different authors, consider that this function underestimates extreme quantiles in the Mediterranean area (Bacro and Chaouche, 2006).

Consequently, current investigations try to update actual IDF laws in Spain, incorporating new rain gauged stations net and new data, from the 60's until nowadays. Besides, innovations are studied in methodology incorporating regional analysis into the study. And finally, a more adequate distribution will be chosen for adjustment.

2. DATA

The Spanish National Meteorological Institute provided the authors with the existing data from the 63 available stations in the peninsular area, and that implied three times more than those actually used. The Durations were the same as traditionally (5, 10, 15, 20, 30, 60, 120, 180, 360, 720 minutes and 24 hours) but at least another 20 years were provided. Figure 1 shows the location of these stations in Spain, and table 1 shows codes and record lengths.

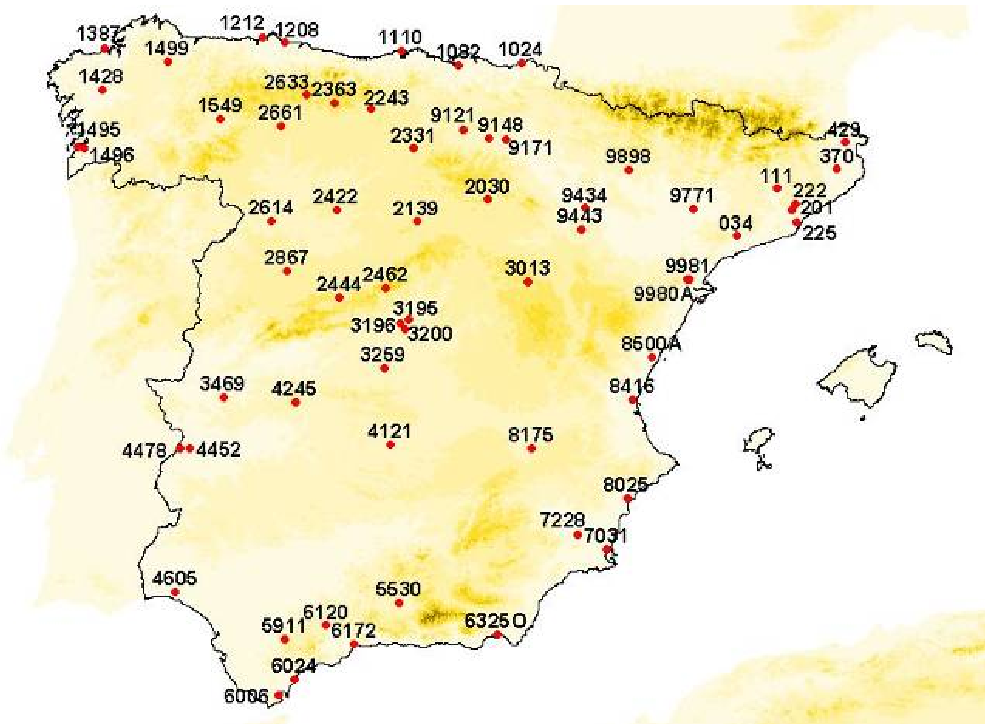

Figure 1 Available pluviograph stations in the Spanish peninsular area.

Table 1 Summary of Stations, Codes and record lengths, provided by the Spanish National Meteorological Institute.

Code	Station	Record length (years)
0034	Valls	25
0111	Sallent	16
0201	Barcelona	71
0222	Caldas Mombuy	16
0225	Sabadell	35
0370	Gerona	33
0429	Figueras	41
1024	S.Sebastian	65
1082	Sondica	30
1110	Santander	41
1208	Gijón	47
1212	Arnao	23
1387	Coruña	68
1428	Santiago	24
1495	Vigo	24
1496	Vigo (Peinador)	23
1499	Punto Centro	19
1549	Ponferrada	41
2030	Soria	30
2139	Linares	18
2243	P. Aguilar	19
2331	Burgos	33
2363	P.compuerto	16
2422	Valladolid	45
2444	Avila	39
2462	Navacerrada	16
2614	Zamora	30
2633	P.Porma	17
2661	León	24
2867	Salamanca	41
3013	Molina de Aragón	44
3195	Madrid-Retiro	41
3196	Madrid-4V	34

Code	Station	Record length (years)
3200	Getafe	30
3259	Toledo	44
3469	Caceres	49
4121	Ciudadreal	35
4245	Guadalupe	16
4452	Badajoz (Talavera)	26
4478	Badajoz (instituto)	35
4605	Huelva	21
5530	Chauchina	15
5911	Grazalema	16
6006	Algeciras	16
6024	Guadarranque	18
6120	Guadalhorce	23
6172	Málaga	23
7031	Murcia S.Javier	30
7228	Murcia Alcantarilla	24
8025	Alicante C. jardín	25
8175	Albacete	29
8416	Valencia	26
8500a	Castellón	15
9121	Haro	33
9148	Logroño	50
9171	Cabreja	15
9434	Zaragoza	34
9443	Mezalocha	32
9771	Lérida	31
9898	Huesca	23
9980A	Tortosa	23
9981	Roquetas	36
63250	Almería	20

3. METHODS USED IN GAUGED STATIONS

Due to insufficient stations, it was not possible to apply regional analysis as traditionally used, and a new way to apply this technique was proposed, joining series - for different durations - in the same station to form homogeneous regions.

Different authors have already pointed out different behaviours when considering shorter or larger durations than an hour (Hershfield, 1961; Bell, 1969; Ferreri y Ferro, 1990; Porras y Porras, 2001). Besides, in Spain, LLasat (1998) recommends classifying rainfall according to their source -convective or non convective- before studying IDF curves, and indicates that convective episodes usually last less than an hour. Consequently, among the possibilities, regional analysis was applied in the same station, forming two regions with short/large duration series, establishing one hour as the threshold to classify homogeneous regions.

3.1 Homogeneity analysis

The first step implied homogeneity study, and homogeneity in regions was based on L-moments following Hosking and Wallis methodology, (de Salas and Fernández, in press). This analysis let the authors accept one hour as the threshold to establish two regions in the same station.

3.2 Choosing a function distribution

A dimensionless sample -corresponding to different duration in the homogeneous region- was adjusted to the SQRT-ET max. distribution for different reasons (Ferrer and Ardiles, 1994):

-It is the only one that has been specifically proposed for maximum daily rainfall analysis, and it has been used in Spain to estimate annual maximum daily rainfall quantiles with good results.

-It yields more conservative results than the traditional Gumbel distribution for high return periods.

-It is capable of providing a good description of the main sample statistics concerning the right hand tail of the distribution, a fact that has been checked applying Montecarlo simulation techniques.

The SQRT-ET máx equation, eq. 1., is based on two parameters. Shape parameter depends on the sample scale parameter, so final analysis should be based on scale parameter.

$$F(x) = exp\left[-k(1+\sqrt{\alpha \cdot k})exp(-\sqrt{\alpha \cdot x})\right] \quad (1)$$

Where, k is a frequency parameter and α is scale parameter.

3.3 Estimating parameters

Next point implied estimating parameters, and moments and maximum likelihood were used.

The criteria to select the best method were Kolmogorov-Smirnov Test and graphic analysis. When both estimations were accepted applying Kolmogorov-Smirnov Test, dimensionless quantiles were plotted against return period, and the single dimensionless series that forms the region was plotted together. P-plotting position estimator for extreme values was proposed by Hosking and Wallis (1997), eq. 2.,

$$p_{jn}=(j-0,35)/n \quad (2)$$

Where,

j, is the position, in increasing order.

n, is the sample size.

If both estimations were over observed data, both methods would underestimate, see Figure 2, and authors chose the one that provided closest estimations to observed data, so that under-estimations were the less significant. If one method provided underestimations and the other over estimations, the latter would be chosen. Finally, if both methods provided overestimations, Figure 2, closest method to observed data for usual return periods would be the one chosen so that estimations were not greatly overestimated. In this case, Figure 2, the method of moments would be chosen.

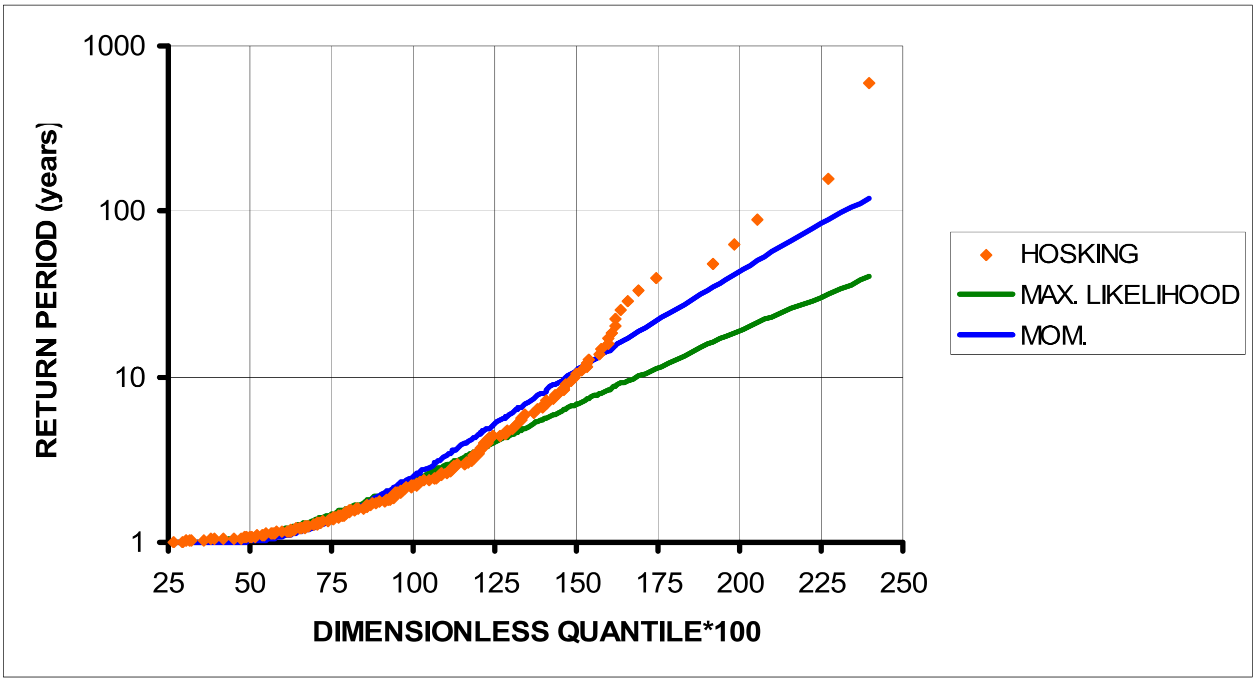

Figure 2 Dimensionless quantiles in "short durations" region, in Sabadell Station (0225)

4. RESULTS AND VALIDATION IN GAUGED STATIONS

After regionalization technique was applied on the 63 available gauged stations (de Salas, 2005; de Salas and Fernandez, 2005 in press), two regions were established in every station, "short durations" (≤ 1 hour) and "large durations" (> 1 hour), and thus, I(d;T,) can be expressed as eq. 3.:

$$I(d;T)_{station}=Q\ (T)_{short/large\ durations}*\overline{I}(d)_{station} \quad (3)$$

Where,

$Q(T)_{short/large\ durations}$, is "short durations" (≤ 1 hour) or "large durations" (>1hour) dimensionless quantile for T-year return period in gauged stations.

$\bar{I}\ (d)_{station}$, (mm/h), is local factor, in this case, average annual maximum rainfall intensity for the corresponding duration.

4.1 Validation

Two different ways were used to validate the estimations:

a) One, was to generate samples with the adjusted function of distribution and comparing some of their parameters to the observed ones.

Eighteen regions were chosen so that observed coefficients of variations were all represented in the analysis. Table 2 shows the number of regions included in every coefficient of variation interval and the number of chosen regions in each interval. One hundred samples were generated applying Montecarlo simulation, and three parameters were calculated: average, coefficient of variation and coefficient of skewness, and they were compared to observed parameters. Average should be close to one as authors had worked with dimensionless data, and the other two parameters were plotted at the same time with observed ones. Figure 3 is included as an example. These graphic analyses let the authors reach the conclusion, that there was no anomalous behaviour, as observed parameters stayed inside the cloud of generated data parameters.

Table 2 Number of regions included in the proposed coefficient of variation intervals and the number of chosen regions in each interval.

Cv Interval	Number of Regions	Number of regions used in validation
(0,2-0,3]	15	2
(0,3-0,4]	46	6
(0,4-0,5]	42	6
(0,5-0,6]	16	2
(0,6-0,7]	5	1
(0,7-0,84]	2	1

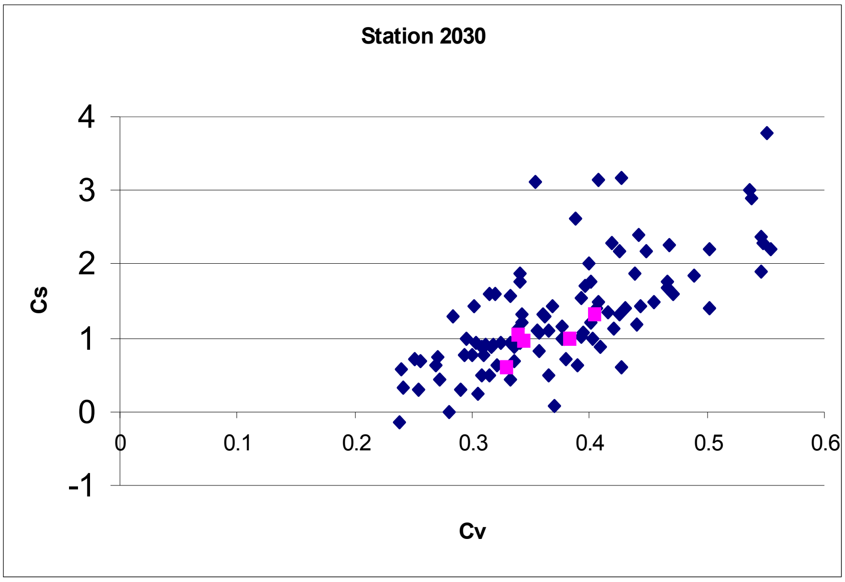

Figure 3 Cv-Cs in generated samples (blue), and in observed samples (pink) at the “large durations” region in station 2030.

b) Robustness of regional and local analysis was compared. This analysis was based on comparing dimensionless quantiles when using every data and when eliminating the highest year data, Figure 4. One can see that regional analysis provides nearly the same quantiles when all data are used and when eliminating extreme year; on the contrary, local analysis provides different quantiles, being this effect more important the higher the return period is. This behaviour was more important in regions which had higher Cv.

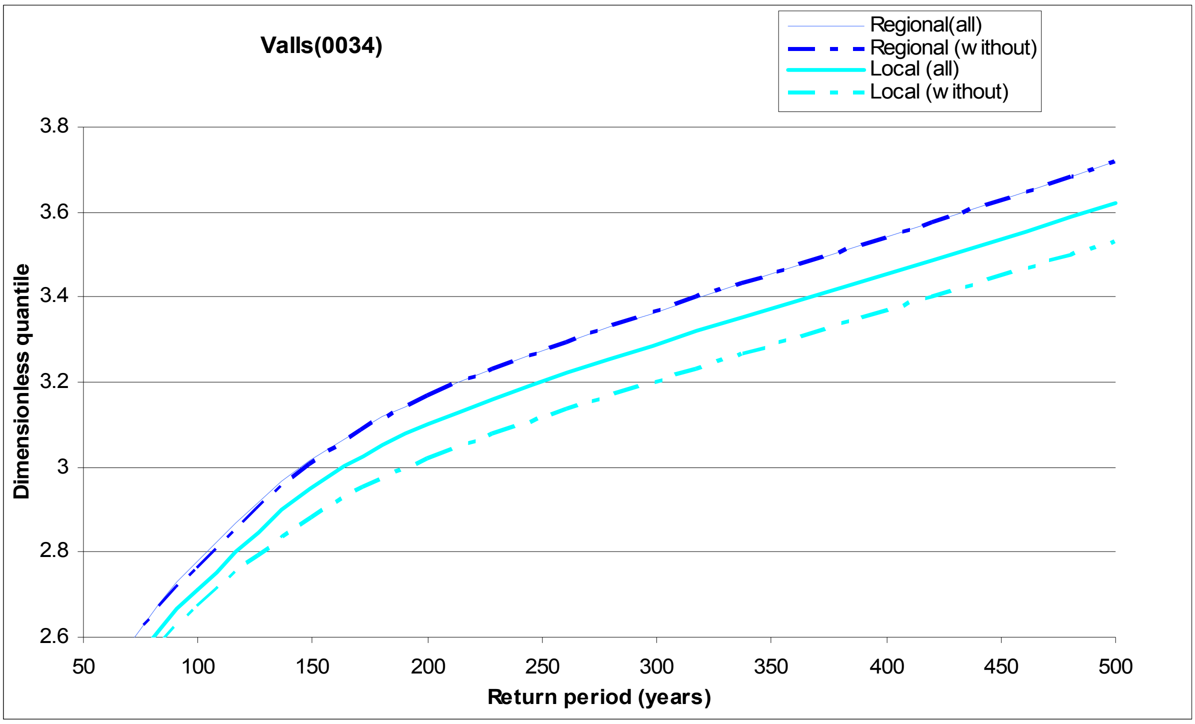

Figure 4 Dimensionless quantiles in regional and local analysis using every data and eliminating extreme year in Valls (0034)

5. METHOD USED IN THE REST OF THE TERRITORY

An expression relating I(d,T) and intensity for a 24 hour period and the same return period, can be defined in gauged stations as eq.4.

$$\left[\frac{I(d;T)}{I(24;T)}\right]_{GS} = \frac{Q^{GS}(T)_{short/large} \cdot \overline{I^{GS}{}_{d}}}{Q^{GS}(T)_{large} \cdot \overline{I^{GS}{}_{24}}} \qquad (4)$$

Where, GS refers to gauged stations

24 annual maximum rainfall intensity is related to annual maximum daily precipitation, AMDP, so, it is more adequate to base estimations on AMDP(T) due to more abundant pluviometer network and longer record lengths. Besides, regional analysis has been applied over AMDP (Ministerio de Fomento, 1999), and consequently, eq. 4 becomes eq. 5.

$$\left[\frac{I(d;T)}{I(24;T)}\right]_{GS} = \frac{Q^{GS}(T)_{short/large} \cdot \overline{I^{GS}{}_{d}}}{Q^{GS}(T)_{large} \cdot \overline{I^{GS}{}_{24}}} = \frac{Q^{GS}(T)_{short/large} \cdot \overline{I^{GS}{}_{d}}}{Q^{GS}(T)_{AMPD} \cdot \overline{I^{GS}{}_{24}}} \qquad (5)$$

Where,

$Q^{GS}(T)_{AMPD}$, is the dimensionless quantile in gauged stations for T-return period, obtained when applying regionalization on AMDP. These data are available all over the Spanish Peninsular area (Ministerio de Fomento, 1999).

If eq. 5 is applied in places where no gauged station is available, both factors in numerator are unknown.

In this paper, two functions are analyzed in gauged stations, one relating dimensionless quantiles to return period –h(T)- and another one -g(d)- relating mean annual maximum intensities to duration. Authors propose a methodology to extend these two functions everywhere in the Spanish peninsulararea, so that final expression for I(d,T) can be obtained in eq. 6.

$$\left[\frac{I(d;T)}{I(24;T)}\right]_{site} = \frac{Q^{site}(T)_{short/large} \cdot \overline{I^{site}{}_d}}{Q^{site}(T)_{AMDP} \cdot \overline{I^{site}{}_{24}}} \cong h(T) * g(d) \qquad (6)$$

This expression agrees with consulted papers (Koutsoyiannis, D *et al.*1998) indicating the advantage of using two independent functions, one attached to return period and another one to duration.

5.1 h(T) function

It was analyzed whether $Q^{GS}(T)_{short/large}$ is systematically related to $Q^{GS}(T)_{AMDP}$ in gauged stations and a methodology was proposed to apply this function in the whole territory.

5.2 g(d) function

A function relating intensity to duration is analysed in gauged stations and a methodology was proposed to apply this function in the whole territory.

6. RESULTS IN THE REST OF THE COUNTRY

6.1 h(T) function

Spatial analysis of the quotient $\frac{Q^{GS}(T)_{short/large}}{Q^{GS}(T)_{AMDP}}$ let the authors establish two geographical regions with different behaviours, Figure 5 and 6, and in each one a logarithmic function was used for adjustment, eq.7.

$$h(T) = a \bullet (LnT)^2 + b \bullet (Ln\ T) + c \qquad (7)$$

Where, T is return period, and a, b, c parameters are shown in Table 3.

R^2 is the correlation coefficient

LnT, is the T- year Napierian logarithm.

Table 3 Parameter values in every zone and region

	"Short durations" region		" Large durations" region	
	Zone 1	**Zone 2**	**Zone 1**	**Zone 2**
a	$-4*10^{-4}$	$-7*10^{-3}$	$1,2*10^{-3}$	$-3,7*10^{-3}$
b	$9,2*10^{-3}$	$106,6*10^{-3}$	$13,6*10^{-3}$	$55*10^{-3}$
c	1,004	0,909	1,022	0,954
R^2	0,991	0,998	0,991	0,959

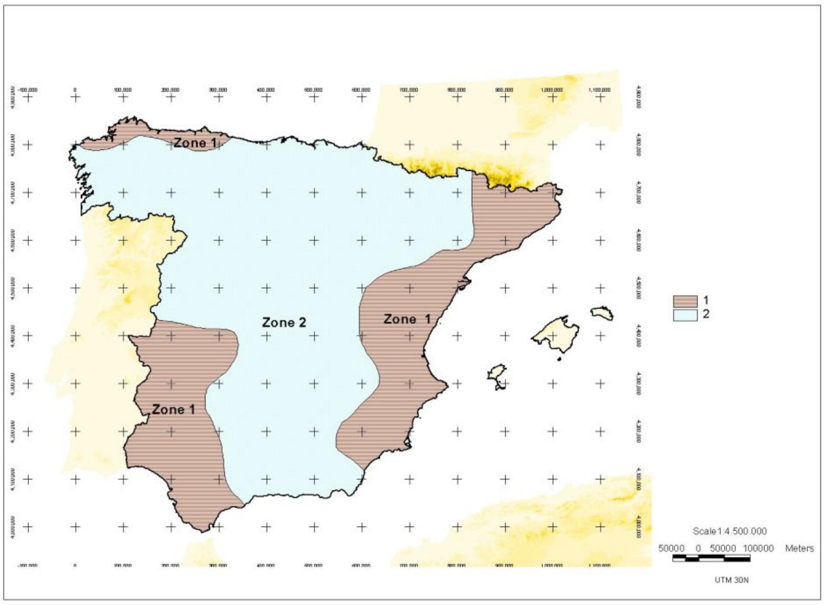

Figure 5 Zones 1-2 in "Short durations" region in Spain

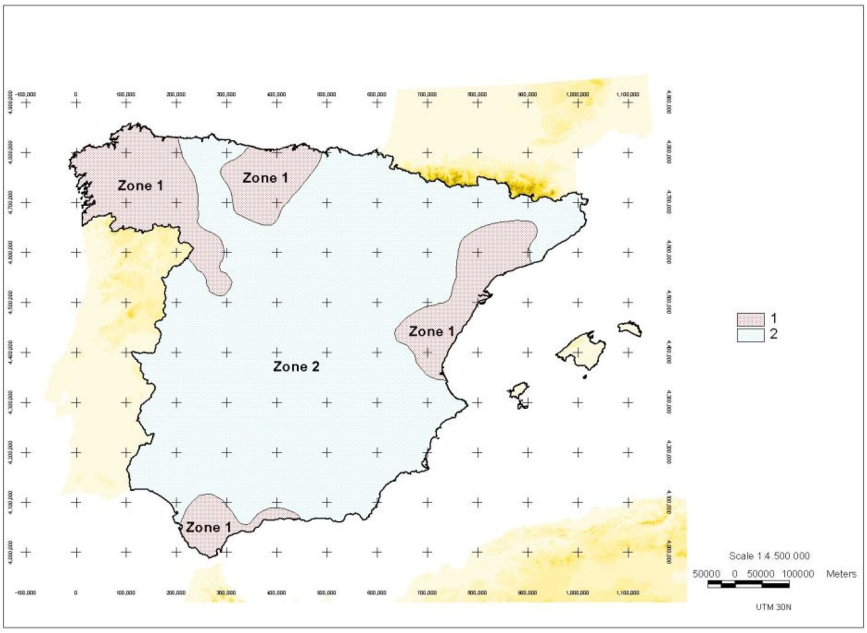

Figure 6 Zones 1-2 in "Large durations" region in Spain.

6.2 g(d) function.

A potential function was proposed, eq. 8. It is similar to the one actually used (Ministerio de Obras Públicas, Transporte y Medio Ambiente, 1987) but it depends on two parameters instead of just one in order to describe observed variability more adequately.

$$g(d) = \frac{\bar{I}_d}{\bar{I}_{24}} = K^{\frac{24^a - d^a}{24^a - 1}} \qquad (8)$$

The following table, Table 4, presents “K” and “a” values in gauged stations. In every case coefficient of correlation was higher than 0,98.

Table 4 “K” and “a” values in every gauged station

Code	Station	a	$K=\bar{I}_1/\bar{I}_{24}$
0034	Valls	0,2467	12,8
0111	Sallent	0,1343	9,5
0201	Barcelona	0,1525	11,2
0222	Caldas Mombuy	0,2398	13,2
0225	Sabadell	0,1350	11,7
0370	Gerona	0,1185	7,6
0429	Figueras	0,1029	8,9
1024	S,Sebastián	0,0600	7,2
1082	Sondica	0,0600	6,9
1110	Santander	0,1146	7,5
1208	Gijón	0,0819	7,0
1212	Arnao	-0,0489	5,6
1387	Coruña	0,0650	8,1
1428	Santiago	0,0089	5,0
1495	Vigo	0,0390	6,2
1496	Vigo(Peina-dor)	0,1447	6,9
1499	Punto Centro	0,1795	8,8
1549	Ponferrada	0,0557	8,7
2030	Soria	0,0882	10,1
2139	Linares	0,1372	11,9
2243	P, Aguilar	0,0787	8,7
2331	Burgos	0,0884	10,0
2363	P,compuerto	0,1044	8,4
2422	Valladolid	0,0704	10,0

Code	Station	a	$K=\bar{I}_1/\bar{I}_{24}$
2444	Avila	0,1555	12,8
2462	Navacerrada	-0,0418	4,7
2614	Zamora	0,1071	11,7
2633	P,Porma	0,0128	5,5
2661	León	0,0767	7,4
2867	Salamanca	0,1028	10,4
3013	Molina	0,1225	11,3
3195	Madrid-retiro	0,0938	9,0
3196	Madrid-4v	0,0972	9,1
3200	Getafe	0,1345	10,4
3259	Toledo	0,0847	11,6
3469	Cáceres	0,1287	9,9
4121	Ciudadreal	0,0999	10,4
4245	Guadalupe	-0,125	4,8
4452	Badajoz(Talavera	0,1390	10,2
4478	Badajoz(Instituto)	0,0859	9,6
4605	Huelva	0,1335	10,9
5530	Chauchina	0,0644	9,2
5911	Grazalema	-0,0405	4,0
6006	Algeciras	0,0608	7,0
6024	Guadarran-que	0,1057	5,7
6120	Guadalhorce	0,1061	7,3
6172	Málaga	0,2908	9,0
7031	Murcia S,Javier	0,1573	12,2

Code	Station	a	$K = \bar{I}_1/\bar{I}_{24}$
7228	Murcia alcantarilla	0,1632	11,9
8025	Alicante C,jardín	0,2464	12,3
8175	Albacete	0,1185	12,7
8416	Valencia	0,1221	8,4
8500a	Castellón	0,1797	10,6
9121	Haro	0,1191	10,6
9148	Logroño	0,1190	10,8
9171	Cabreja	0,0177	9,0

Code	Station	a	$K = \bar{I}_1/\bar{I}_{24}$
9434	Zaragoza	0,1037	9,2
9443	Mezalocha	0,1346	10,9
9771	Lerida	0,1224	13,1
9898	Huesca	0,0389	8,4
9980a	Tortosa	0,1947	10,3
9981	Roquetas	0,1416	9,5
63250	Almería	0,1969	13,8

6.3 Extending g(d) function to the rest of the Spanish peninsular territory.

Three solutions are established, and it is up to the user to adopt one of the three, depending on the studied site:

- If the site is close to a gauged station, and meteorological conditions, situation, and orientation are similar, “K” and “a” values in gauged station can be used.
- If the site is near several gauged stations, “K” and “a” can be weighed depending on distance.
- The third option consists of using “iso-K” and “iso-a” maps which are based on gauged stations values. The Figures 7 and 8 show iso-K and iso-a maps.

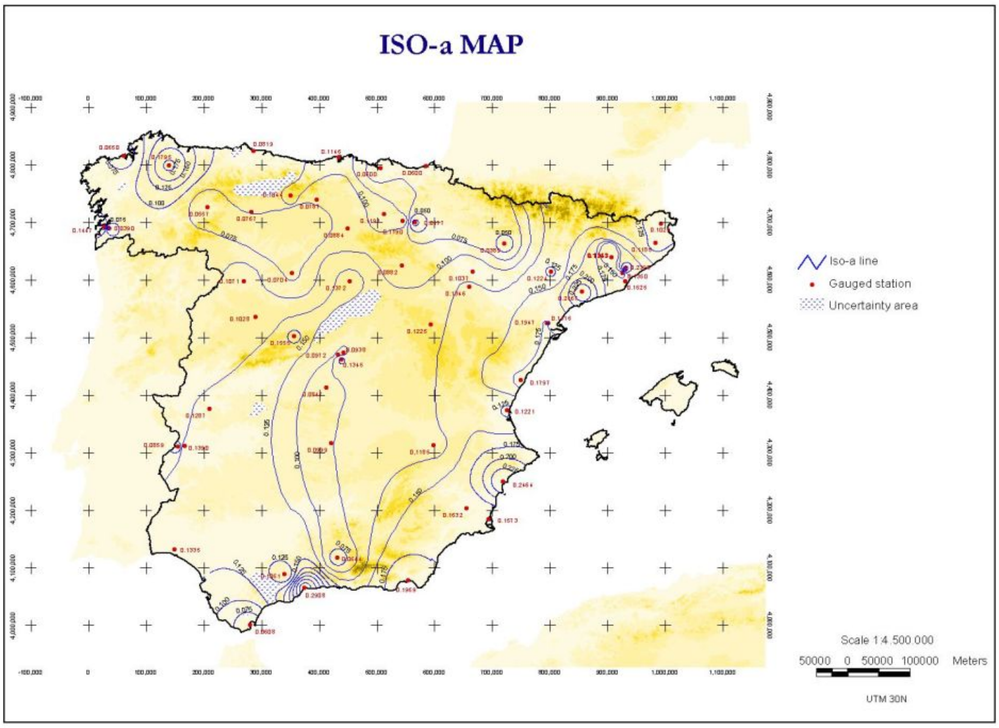

Figure 7 Iso-a map in Spanish Peninsular Area

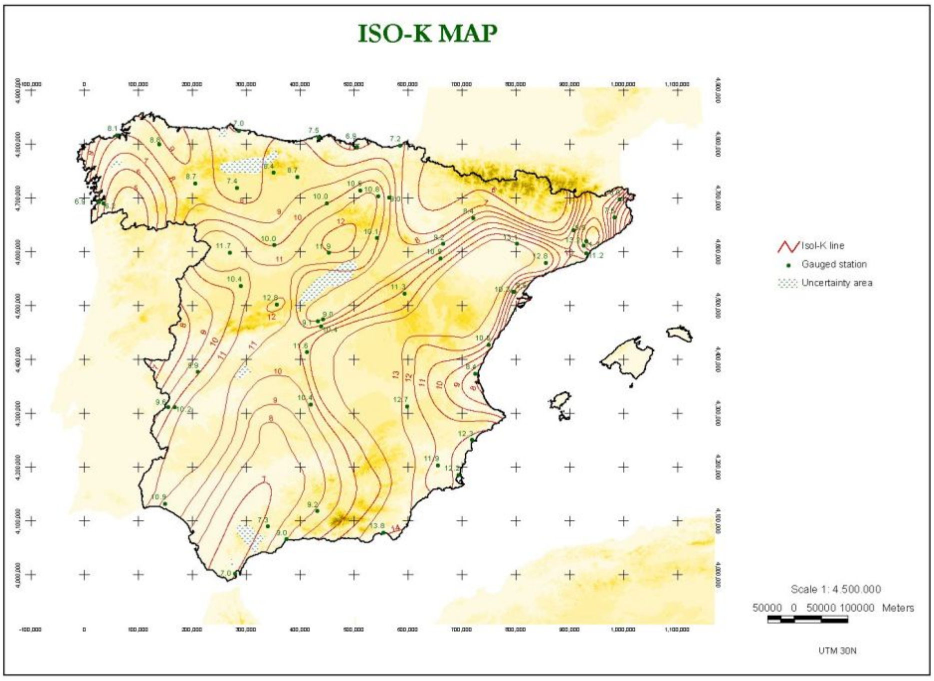

Figure 8 Iso-K map in Spanish Peninsular Area

Dotted areas in iso-line Maps are zones where gauged stations values were not used to design iso-line Maps due to their special rainfall behaviour (mountains, orientation….). In those cases it would be more adequate to use gauged station values.

6.4 Developing a GIS

The whole spatial information was geo-referred using UTM 30N coordinates, and spatial adopted resolution was 1.000m x1.000m. Besides, spline interpolating method, six reference stations and 1.000m resolution were used for iso-K Map; inverse distance weighing 2 (IDW 2) interpolation method, 12 referred stations and 1.000m resolution was adopted for iso-a Map. A Gis application was developed, and it is available in the following web site:
http://www.forestales.upm.es/hidraulica/paginas/programas/programas.htm

A map of the Spanish Peninsular area is provided, and it is possible to make two zooms to locate the site of interest. The needed parameters to estimate I(d,T), eq. 6, are obtained, and the proper application estimates I(d,T) when incorporating the parameters in the corresponding cells.

7. DISCUSSION

Under this title, the IDF which is actually being used in Spain and the new expression which is proposed in this paper will be analyzed. In second place, I(d,T) estimations will be compared in gauged stations when applying regionalization, eq. 3., and when using g(d) and h(T) expressions, eq. 6.

7.1 Actually used IDF relationship versus proposed IDF

It is important to insist on the fact that the IDF expression actually used is based on a local analysis on the 21 available gauged stations. That implies that just 20-25 data were used for adjustment, and that is not enough when considering high return periods. Besides, the way to extend results to the rest of the territory is based on 21 stations which can be quite difficult to accept. The proposed expression is based on 63. That would imply three times more those stations actually used; Moreover, data have also been increased, so, the volume of information is not three times but nearly sixty times more than presently used considering that at least twenty more years have been included. In the best conditions forty more years could have been included. At the same time, regionalization has been used in the same station, and data for different durations have been joined into a homogeneous region, so, information has been increased even more, nearly three hundred times in one case and three hundred and sixty in the other. In conclusion, this study implies an important increase of information which will turn into key improvements in estimations.

Additionally, the functions of distribution can also be compared. Basically, Gumbel distribution presents a constant coefficient of skewness of 1,14 and recent investigations insist on the idea that *extreme rainfall events in the Mediterranean area are not under the Gumbel law domain* (Bacro and Chaouche, 2006). On the other hand, SQRT-ET máx coefficient of skewness is always >1,14, and its estimation is based on sample coefficient of variation, and that seems more adequate for this kind of event (Ferrer and Ardiles, 1994).

7.2 Proposed IDF function versus expression for the rest of the territory

The only way to analyze whether the expression for generalization is suitable or not, is to compare, in every gauged station, the results of the regionalization, eq. 3, and what could be obtained if we consider that it as a place with no data and therefore applying the proposed model, eq. 6.

Table 4 shows the average relative differences in estimations, S(%), when applying regionalization and functions h(T) and g(d) in gauged stations.

The expression for S(%) is,

$$S(\%) = \frac{I(d;T)_{regionalizatión} - I(d;T)_{g-h}}{I(d;T)_{regionalización}} * 100 \tag{8}$$

Where,

$I(d;T)_{regionalization,}$ is the annual maximum intensity for d-duration (hours) and T-return period (years), applying regionalization, $I(d;T)_{station}$=Q $(T)_{short/large\ durations}$* $\overline{I(d)}_{station}$

$I(d;T)_{g\text{-}h}$, is the annual maximum intensity for d-duration (hours) and T-return period (years), applying g(d) and h(T) functions, $I(d,T)_{station}$=h(T)*g(d)

Negative values indicate I(d,T) estimation using g(d) and h(T) functions is higher than applying regional approach.

Table 4 indicates that, considering all of them, average differences S(%) are quite small; "short durations" in defect (1.52 % , 0.86%) meanwhile "large durations", more frequently used, in excess (-5.04%, -4,2%).

Table 4 Summary of S(%) for "short/large durations" regions, and short and large return periods

	Short durations region T (2-25)	Short durations region T(50-500)	Large durations region T(2-25)	Large durations region T(50-500)
Mean	**1.52**	**0.86**	**-5.04**	**-4.21**
Cv	**3.06**	**11.39**	**-1.24**	**-2.21**

If analysis is obtained station by station, Table 5, one can see that differences are very small and only in one case S(%) takes a -30% value for high return periods, but as it is negative, it implies eq. 6. would estimate in excess.

Table 5 Average S(%) values for the correspondent return period intervals in every station

STATIONS	S T(2-25)	S T(50-500)	L T(2-25)	L T(50-500)
63250	-2.89	-5.92	-8.06	1.29
34	6.62	10.60	-12.91	-12.00
111	-5.45	-19.16	-3.33	-7.36
201	-3.03	-11.13	-11.72	-16.50
225	-2.86	-15.45	-9.67	-15.77
370	-4.64	-15.17	-8.15	-8.71
429	-2.04	-4.75	-2.89	8.64
1024	-2.50	-11.79	-6.59	-9.76
1082	-1.49	-4.97	-4.82	-4.07
1110	-1.45	-7.97	-8.08	-5.72
1208	1.47	3.18	0.30	2.94
1212	-0.60	-0.02	1.73	-3.09
1387	-1.30	0.98	0.31	4.51
1496	5.78	-2.37	-3.89	-0.82
1428	19.22	18.79	11.10	9.27
1495	0.13	-1.54	4.72	14.39
1499	4.85	13.19	-14.45	-9.48
1549	8.05	17.04	-3.72	-6.51
2030	0.48	-0.49	-11.52	-11.07
2139	7.75	17.25	-8.57	-5.62
2243	8.61	10.33	-4.80	-1.08
2331	0.76	-7.56	-5.05	-3.51
2363	3.48	6.69	-16.73	-16.38
2422	-0.36	-4.98	-3.90	-2.51
2444	0.35	9.59	-11.60	-0.92
2462	-3.41	-11.08	5.61	8.96
2614	3.64	9.25	-7.50	0.91
2633	0.00	0.00	0.00	0.00
2661	6.07	11.00	-2.98	-3.55
2867	9.18	13.63	-8.22	-0.90
3013	3.08	3.63	-12.61	-21.28
3195	0.00	0.00	0.00	0.00

STATIONS	S T(2-25)	S T(50-500)	L T(2-25)	L T(50-500)
3196	0.19	-6.85	-7.39	-8.64
3200	-1.59	-7.19	-4.95	-4.96
3259	-2.23	-6.37	-2.04	-0.95
3469	5.49	10.71	-8.33	-10.90
4121	6.48	15.99	-6.47	-13.37
4245	2.79	4.93	12.02	6.59
4452	7.94	18.02	4.99	19.26
4478	0.91	2.07	-4.64	-6.68
4605	-1.04	-0.85	-8.47	-11.95
5530	0.88	-4.21	2.41	3.69
5911	-10.09	-25.18	-0.80	-8.20
6006	-2.48	-5.17	-4.69	-18.29
6024	3.36	12.22	4.71	15.60
6120	-1.17	1.00	6.84	17.86
6172	0.47	0.02	-5.84	-3.46
7031	2.03	0.52	-12.50	-13.26
7228	1.10	3.94	-19.41	-29.91
8025	2.52	5.38	-10.72	-7.63
8175	1.82	-1.64	-8.44	-9.84
8416	-1.38	-8.09	-1.92	-2.12
9121	9.38	17.99	-2.91	8.56
9148	3.45	8.23	-13.32	-14.89
9171	0.48	-3.87	-2.63	-9.37
9434	-5.00	-7.11	-5.21	-2.04
9443	1.71	-6.26	-7.76	-12.13
9771	5.50	5.33	-7.70	-5.37
9898	8.98	16.42	-3.02	-4.35
9981	0.04	-2.40	-5.55	0.65
8500a	-4.12	-3.04	-12.49	-10.19
9980A	0.08	-2.14	-8.01	-9.04

8. CONCLUSION

As a conclusion, one can resume that:

- The proposed method in gauged stations involves a very important increase of information, which can result in a considerable improvement on adjustments.
- Regionalization incorporates robustness into estimations.
- A more adequate function of distribution has been chosen to describe rainfall intensity.
- A new methodology is proposed to extend obtained results to the rest of the Spanish territory, and that will imply significant improvements due to:
  - Regionalization robustness incorporation in h(T) function.
  - More adequate g(d) function and isoline maps, as more stations and data have been used. A new parameter, "a", has been incorporated which provides more flexibility and observed spatial variability.
- Finally, based on a GIS, an application has been developed –MAXIN– which facilitates estimations to users. It is available in the web site:

http://www.forestales.upm.es/hidraulica/paginas/programas/programas.htm

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